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ICHTHYOLOGY.—*The osteology and relationships of the Argentinidae, a family of oceanic fishes.*[1] Wilbert McLeod Chapman, U. S. Fish and Wildlife Service. (Communicated by Leonard P. Schultz.)

The genus *Argentina* was proposed by Linnaeus and was known before him by Gronow and Artedi. The classification of the argentines has ever since been indescribably mixed up with the Salmonidae, Bathylagidae, Retropinnidae, Osmeridae, Microstomidae, etc. All ichthyologists, up to and including Günther (1866), retained these fishes in the family Salmonidae, and this was continued to as recently as 1929 (Kyle and Ehrenbaum, 1929). Gill (1861) recognized Bonaparte's splitting of the Salmoninae and the Argentininae, but he included part of the osmerid fishes in each of the two subfamilies. This he corrected (Gill, 1862) by including all the smelts with *Argentina* in the Argentininae, placing *Microstoma* in a separate family, and introducing a new subfamily in the Salmonidae for *Retropinna.*

Later, Gill (1884) proposed full family status for the group, although he did not give any diagnosis of the family. As late as 1936 (Fowler, 1936), the smelts and argentines were being grouped together in the Argentinidae.

Regan (1914) first showed the differences between, and clearly defined, the Argentinidae and Osmeridae. His classification has been generally accepted, and further anatomical work (Chapman, 1941) has shown it to be well-founded. Regan, however, considered *Bathylagus* to be an Argentinidae and was followed in this by Norman (1930), Parr (1931), and Beebe (1933), although others, including Barnard (1925), placed *Bathylagus* in the Microstomidae. It has been recently shown (Chapman, 1942) that *Bathylagus* and *Leuroglossus* are only distantly related to *Argentina,* not much more closely related to *Microstoma,* and should be placed in the family Bathylagidae. *Leuroglossus* had been formerly placed in the Argentinidae (Jordan, 1923) and in the Osmeridae (Soldatov and Lindberg, 1930).

As thus restricted, then, the family Argentinidae contains the single genus *Argentina,* of which *Silus* Reinhardt, 1833, *Acantholepis* Kröyer, 1846, and *Glossanodon* Guichenot, 1866, are synonyms. It is the purpose of the present report to describe the osteology of *Argentina* and define the proper position of the Argentinidae in the ichthyological system.

The report is based upon dissections of two specimens of *Argentina sphyraena,* one collected in Christiania Fjord, Norway, by Robert Collett (U.S.N.M. no. 23013), about 192 mm long, and the other taken at Christiania, Norway, by M. G. Hetting (U.S.N.M. no. 17461), about 125 mm long. It is a pleasure to acknowledge the kindness of Dr. Leonard P. Schultz, curator of fishes, U. S. National Museum, in permitting me to work on these specimens.

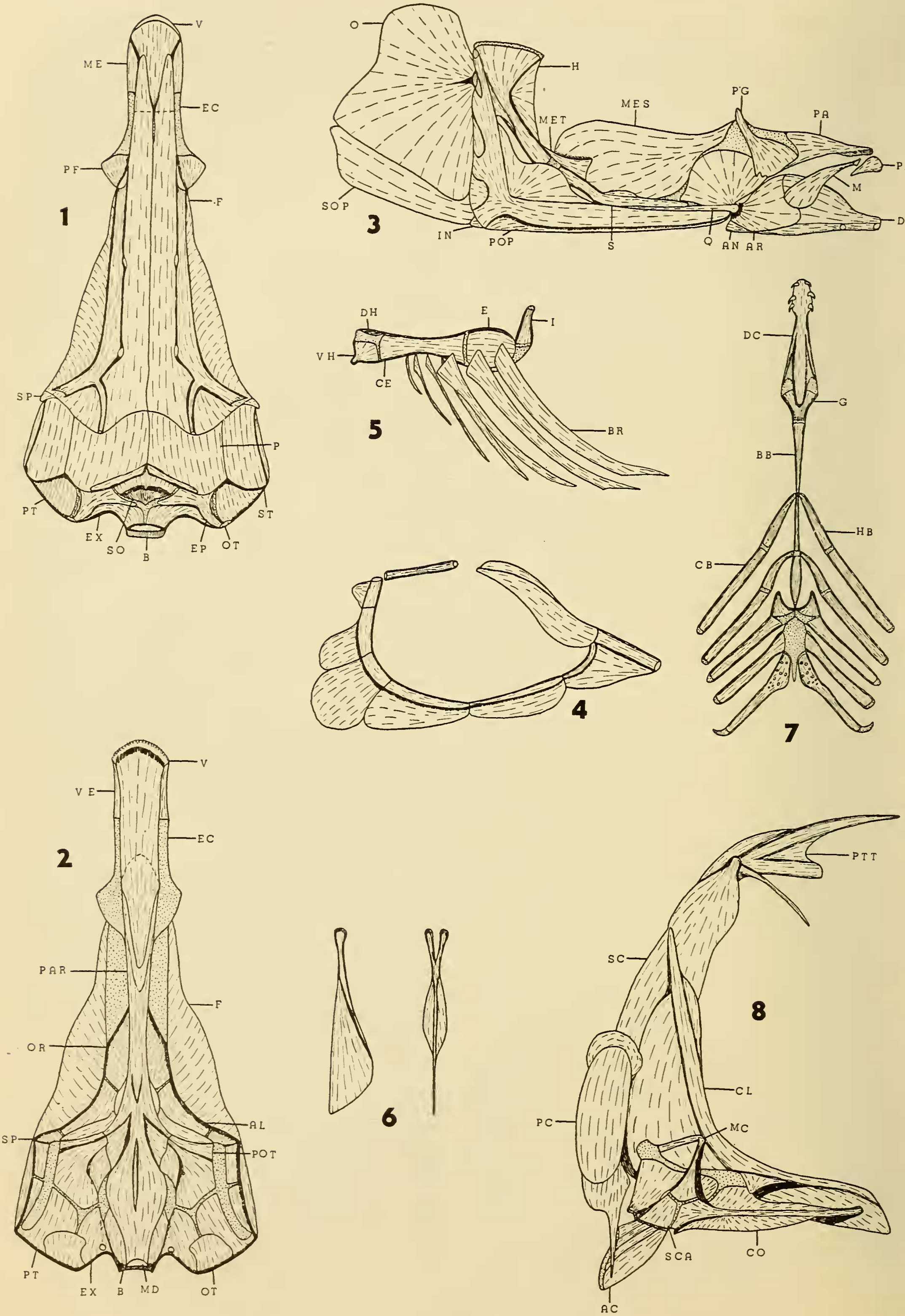
[1] Received September 26, 1941.

THE CRANIUM

The *ethmoid cartilage* (Figs. 1 and 2) is much less developed than in the typical salmonoid cranium. It extends anteriorly a little beyond the end of the mesethmoid to end on the extended vomer. Between the nasal capsules there is a long narrow foramen in the cartilage. The cartilage which forms the dorsal roof of this foramen is an extension of that which lies under the mesethmoid. The cartilage forming the floor of the foramen ends anteriorly squarely against the ventral ethmoid which indeed appears to be only an ossification of the anterior end of this body of cartilage. In the region of the prefrontals the two bodies of cartilage are united but the presence of the large mesial foramen of the olfactory nerve between the prefrontals restricts their union to a strip of cartilage along the inner edge of each prefrontal. Behind the prefrontals the dorsal cartilage splits and sends a broad, but thin, band of cartilage back to the orbitosphenoid. These two bands of cartilage form the ventral protection of the anterior end of the brain cavity from the orbitosphenoid to the prefrontals. The ventral body of cartilage is broadest and thickest between the prefrontals. A little ahead of these bones it puts out a thickened nubbin of cartilage which aids in the articulation of the palatine arch with the cranium. Directly behind the prefrontal the thickened dorsal surface of this body of cartilage is slightly indented and here are inserted the anterior eye muscles. The cartilage then tapers rapidly to a sharp point directly under the base of the anterior spike of the orbitosphenoid. This point is hidden in a deep cavity in the dorsal surface of the parasphenoid behind the end of the vomer. The thin spatulate end of the parasphenoid does not reach to the ventral ethmoid and, therefore, the vomer for a way lies directly on the ventral cartilage.

The *mesethmoid* (Fig. 1) is a complex element. In dorsal view it appears as a broad nearly flat shield rounded anteriorly and cut off squarely behind, where it extends under the frontals nearly halfway to the prefrontals. If the dorsal portion of the bone is cut transversely ahead of the frontals there is seen to be a thin blade of ossification extending ventrally between two portions of cartilage so that the appearance of double origin is given the element. There is also a ventral ethmoid ossification. In such fishes as *Thaleichthys*, *Spirinchus* (Chapman, 1941), and the more closely related *Bathylagus* (Chapman, 1942), this bone is completely separated from the mesethmoid by the intervening ethmoid cartilage. But in *Argentina* the mesethmoid and ventral ethmoid are ankylosed around their anterior borders. The posterior ends of the bones are well separated and the ventral ethmoid does not extend as far posteriorly as does the mesethmoid. It does not reach to the parasphenoid. The broad shaft of the vomer covers most of the ventral surface of the bone.

The *frontals* (Figs. 1 and 2) are separate for their entire length, but are divergent only anteriorly where they part to expose the mesethmoid. The interorbital space is depressed to form a broad V-shaped trough. At the upper edges of the trough, near the outer edge of each bone, runs the closed tube of the sensory canal. The tube ends over the prefrontals in a large pore, from whence the sensory canal continues through the nasal. The tube has branches posteriorly, over the sphenotic, and sends one branch to the lateral corner of the frontal, where the sensory canal extends down onto the circumorbital bones. A second branch ends in a pore on the posterior corner of the frontal from whence the sensory canal proceeds postero-mesially across the parietal to meet its opposite over the supraoccipital. Lateral to the tube of the sensory canal the edge of the frontal arches over the socket of the eye, thus protecting the latter dorsally. On its underside the frontal bears a ventrally projecting wing in the posterior ocular region which extends over the dorsal edge of the orbitosphenoid, alisphenoid, and a portion of the anterior face of the sphenotic, which serves to bind the bone more securely to the chondrocranial elements. The frontals cover about half the dorsal surface of the small sphenotics. They also slightly overlie the parietals, but only enough so that the bones are well bound together. Near the midline of the cranium the parietal and frontal do little more than meet. There is no cartilage under the bones at this point. The frontals do not reach to the supraoccipital.



FIGS. 1-8.—(See opposite page for explanation.)

The *parietals* (Fig. 1) are thin, broad bones of nearly square shape. The bones meet broadly along the midline where the one on the right overlaps the one on the left very slightly. The parietals cover more than two-thirds of the dorsal surface of the small supraoccipital. Together with the supratemporal, whose edge lies over that of the parietal, the parietal of each side forms a complete osseous roof over the anterior two-thirds of the deep temporal fossa, in which are inserted the anterior trunk muscles, thus forming a deep cavern quite unlike the condition in the salmonoid or other opisthoproctoid fishes, and reminiscent of the condition in *Esox*.

Only a small surface of the *supraoccipital* (Fig. 1) is exposed dorsally between and behind the parietals. The bone sends a broad prong anterolaterally along the sturdy cartilage over the anterior semicircular canal. These prongs are covered by the parietals. In contrast to the condition normally found in the salmonids and osmerids, where the dorsal surface is shield-like, nearly circular and extends at least as far as the frontals, the anterior edge of the supraoccipital of *Argentina* is deeply crescentic so that the parietals actually form part of the roof over the brain cavity. The posterior surface of the supraoccipital is at nearly right angles to the dorsal surface. Its broad shield-like area is concave mesially and ends ventrally in a blunt point where it is widely separated from the foramen magnum by the exoccipitals. Near the dorsal angle of the bone a delicate flange projects posteriorly between the muscles of either side. This is connected with the first interneural by a thin ligament.

The *supratemporal* (Fig. 1) is a thin, but broad, bone which, with the parietal, covers the anterior two-thirds of the temporal fossa. Its entire lateral edge is securely ankylosed to that of the underlying pterotic. Anteriorly the bone overlies the dorsal surface of the sphenotic to such an extent that there is only a narrow slit of the latter exposed between the frontal and supratemporal. Anteromesially the bone rests on the cartilage over the anterior semicircular canal, and here in turn it is covered by the frontal. Along its entire mesial edge the bone overlies, and is securely bound to, the parietal. On the dorsal side of the lateral edge of the bone is the slender tube of the sensory canal, which is not completely closed over dorsally. The sensory canal, after leaving the skull at the end of this bone, extends on to pass through a well-formed tube on the lateral face of the supracleithrum which is indistinguishably fused with that bone.

Each *epiotic* (Fig. 1) presents a small dorsal surface, only a small portion of which is covered by the parietal. The rounded angle of the bone which slopes off posterolaterally encloses the posterior semicircular canal of the inner ear. The tiny dorsal surface not covered by the parietal is flattened and the dorsal fork of the posttemporal is attached there by a broad liga-

ABBREVIATIONS USED ON FIGURES

AC =actinost
AL =alisphenoid
AN =angular
AR =articular
B =basioccipital
BB =basibranchial
BR =branchiostegal ray
CB =ceratobranchial
CE =ceratohyal
CL =cleithrum
CO =coracoid
D =dentary
DC =dental cement bone
DH =dorsal hypohyal
E =epihyal
EC =ethmoid cartilage
EP =epiotic
EX =exoccipital
F =frontal
FM =foramen magnum
G =glossohyal
H =hyomandibular
HB =hypobranchial
I =interhyal
IN =interopercle
M =maxillary
MC =mesocoracoid
MD =myodome
ME =mesethmoid
MES =mesopterygoid
MET =metapterygoid
O =opercle
OR =orbitosphenoid
OT =opisthotic
P =parietal
PA =palatine
PAR =parasphenoid
PC =postcleithrum
PF =prefrontal
PG =pterygoid
PM =premaxillary
POP =preopercle
POT =prootic
PT =pterotic
PTT =posttemporal
Q =quadrate
S =symplectic
SC =supracleithrum
SCA =scapula
SO =supraoccipital
SOP =subopercle
SP =sphenotic
ST =supratemporal
V =vomer
VE =ventral ethmoid
VH =ventral hypohyal

Figs. 1–8.—*Argentina sphyraena* Linnaeus: 1, Dorsal view of cranium of small specimen; 2, ventral view of cranium of small specimen; 3, lateral view of suspensorium of large specimen; 4, circumorbital bones of large specimen; 5, lateral view of hyoid apparatus of large specimen; 6, lateral and dorsal views of urohyal of large specimen; 7, dorsal view of ventral bones of the gill arches of large specimen; 8, mesial view of the shoulder girdle of large specimen. (Figs. 1, 2, and 8, × 3; Figs. 3—7, × $1\frac{1}{4}$, approximately.)

ment. A strongly ossified strut extends laterally under the posterior edge of the parietal and serves to strengthen that thin bone. The anterolateral face of the bone is shallowly concave to form the mesial wall of the temporal fossa. The posterior face of the bone adjacent to the supraoccipital is heavily ossified. Between this flattened surface and the rounded posterolateral corner of the bone, the lower portion of the bone is deeply concave, continuing the adjacent indentation of the exoccipital. The epiotic touches the supraoccipital dorsally, but ventrally the bones are separated by a narrow band of cartilage. A similar band of cartilage separates the epiotic and the exoccipital. The cartilage between the epiotic and pterotic is broader. The opisthotic touches, but does not overlie the epiotic.

The *opisthotic* (Figs. 1 and 2) is a small, thin bone of irregular shape which curves around the cartilage between the epiotic, exoccipital, and pterotic. It is visible from the dorsal aspect, but has no definite dorsal surface. There is an irregular ventral surface of some size lying over the exoccipital, pterotic and the cartilage between the two and extending more than a third of the way to the junction of these two bones with the prootic.

The dorsal surface of the *pterotic* (Figs. 1 and 2) forms most of the floor of the temporal fossa and is mostly excluded from view by the supratemporal. The bone has no definite posterior or lateral surface. It is only a rounded cover over the horizontal semicircular canal and its junction with the posterior semicircular canal. The ventral surface of the bone is marked by the cartilage-lined socket of articulation of the hyomandibular which extends from near the posterodorsal corner of the skull to the junction of the sphenotic and prootic. About half of the hyomandibular articulation is borne on this bone, the rest being on the cartilage between the sphenotic and prootic and, at its anterior end, on the sphenotic. The pterotic is separated from all other cartilage bones of the cranium by a continuous band of cartilage.

The *sphenotic* (Figs. 1 and 2) is a small, but sturdy, bone with three surfaces. The dorsal surface is nearly covered by the frontal and supratemporal. From the corner of the bone a strongly ossified spur which supports the postorbital projects downward. The sphenotic is separated from the pterotic, prootic, and alisphenoid by a continuous, narrow band of cartilage.

The *alisphenoid* (Fig. 2) is a bone of roughly rectangular shape between the orbitosphenoid anteriorly, and the sphenotic and prootic posteriorly. Its dorsal edge is covered by the ventral flange of the frontal. It is separated from the sphenotic by a narrow band of cartilage. The dorsal half of the junction with the prootic is separated by cartilage, but in the lower half the ossifications meet. The anterior ends of the alisphenoids are widely separate.

The *orbitosphenoid* (Fig. 2), which is bilaterally symmetrical, unites the anterior portion of the braincase firmly. On the midline a thin vane of bone projects ventrally. It is extended forward in a fine spike well beyond the main portion of the bone, and a similar, but broader, projection extends posteriorly. From this vane the interorbital septum extends to the parasphenoid. The dorsoposterior corner of the orbitosphenoid is overlapped by the ventral flange of the frontal and thus securely bound to that bone. The entire dorsal edge of the bone abuts on the posterodorsal extension of the ethmoid cartilage. The anteromesial corner is rounded into a cylindrical foramen for the emergence of the large olfactory nerves.

The *prootic* (Fig. 2) is divided into an anterior and lateral face by a sharp ridge that continues the upsweeping line of the parasphenoid wing to the dorsal edge of the prootic at the anterior end of the facet for the hyomandibular. Midway in its length this ridge forms a narrow bridge over the emerging trigeminofacial complex. Two other nerves from this complex emerge in separate foramina on the posterior face of the bone. One extends posteriorly at the dorsal edge of the otolith bulge, the other goes ventrally and emerges on the anterior side of the otolith bulge. On the anterior face of the bone there are also two foramina besides the large opening of the trigeminofacial complex. The dorsalmost one is on the anterior edge of the bone and is not entirely closed, so that it is in fact a deeply rounded notch. The other is more ventral and posterior, directly above the base of the basisphenoid. The two prootics meet ventrally to form the roof of the high, vaulted myodome. The myodome is large anteriorly where its bottom and sides are formed by the wings of the parasphenoid. It forms a deep channel between the otolith bulges, which is hidden from sight by the flat posterior part of the parasphenoid, and opens posteriorly on the basioccipital under the occipital condyle. The lower portion of the posterior face of the prootic curves outward to form part of the otolith bulges. There is a broad band of cartilage between the prootics and basioccipital, but the bands between them and the other cartilage bones is narrow, although continuous.

The *basisphenoid* is a simple, small rod of bone forking at its dorsal end, sending a short arm to each prootic. It ends ventrally in a small cap of cartilage by which it is attached to the parasphenoid. It serves to separate the posterior eye muscles as they enter the myodome, and to bind the postorbital portion of the cranium more securely to the parasphenoid.

The *basioccipital* (Figs. 1 and 2) forms the entire occipital condyle. Here the bone is constricted and heavily ossified. Anteriorly it broadens out and becomes thinner to form the posterior floor of the otolith bulge. A good deal of its ventral surface is covered by the broad posterior end of the parasphenoid.

The *exoccipital* (Figs. 1 and 2) is the principal bone of the posterior part of the cranium. Prominent on its lateral face is the large foramen of the vagus nerve. Below and ahead of this the bone curves outward to form its share of the otolith bulge. The cartilage at the junction of the exoccipital, pterotic, and prootic is not exposed. The exoccipitals send wings mesially over the posterior surface of the cranium which are separated at the midline by a narrow band of cartilage. These wings form the upper part of the foramen magnum and exclude the supraoccipital from that opening. Lateral to the foramen magnum each bone is deeply concave. The exoccipital rests on the dorsal part of the occipital condyle, but does not enter into its formation.

The spatulate anterior end of the *parasphenoid* (Fig. 2) terminates on the ethmoid cartilage under the nasal capsule, well short of the ventral ethmoid. Its ventral surface is broadly grooved for the reception of the posterior end of the vomer shaft. Its dorsal surface, in the same region, is more deeply grooved yet to receive the posterior end of the ethmoid cartilage. The interorbital portion of the bone is most narrow, but is well ossified and strong. Ahead of the prootics the bone expands and sends broad but short wings to those bones. Behind these wings the bone again expands slightly over the broad cartilage area between the prootics and the basioccipital. It then tapers to a broad end below the occipital condyle.

The *vomer* (Figs. 1 and 2) is a large, long bone. It is widest anteriorly where its single row of small conical teeth, and the continuing rows on the palatine, form the entire dentition of the upper jaw. The bone is also most heavily ossified at this point. It projects anterior to the mesethmoid and is visible from the dorsal aspect. From here the broad, thin shaft tapers gradually backward over the ventral ethmoid, ethmoid cartilage, and parasphenoid to end on the latter, well behind the prefrontals.

SPECIAL OSSIFICATIONS OF THE SENSORY SYSTEM

The *nasal* is a long, slender, tubular bone extending from the anterior edge of the frontal, and ending well forward on the mesethmoid. It lies over the dorsal side of the nasal capsule but extends well to the posterior and anterior sides of that structure. It is incompletely closed dorsally so as to form a trough rather than a tube, although it is roughly circular in cross section. The dorsal opening is expanded at each end and in the middle, where pores open to the dorsal surface of the skull.

There are nine circumorbital bones in the smaller specimen and eight in the larger (Fig. 4), whose thin, yet broad, areas form a protective shield for the lateral surface of the skull. The long and broad preorbital (No. 1) has the appearance of two elements that are nearly indistinguishably anastomosed. The bone's inner (and dorsal) edge lies along the frontal. The element lies over the eye and extends anteriorly to the nasal capsule. The anterior half of the dorsal edge is bent over laterally to form a half-closed tube for the sensory canal. No. 2 is a thin, flat, circular bone lying between the preorbital and the lachrymal, but not entirely filling the space between them. This bone is absent in the larger specimen. The broad lachrymal (No. 3) extends forward beyond the end of the frontals where it ends in a sharp point. Its posterior dorsal edge is curved over laterally like that of the preorbital to form a trough for the sensory canal. The rest of the circumorbital bones bear a similar trough along their orbital edges, which in no instance is completely closed over to form a tube. Nos. 5 and 6 overlie each other and are ankylosed securely together but their margins are still distinguishable. No. 7 is rather loosely bound to No. 6 by membranes. No. 8 is a tiny bone lying at the corner of the sphenotic which is little more than the trough of the sensory canal. No. 9 is larger and more slender. It is only a curved shell around the sensory canal, like the nasal, and has no broad base. There is a considerable space between No. 9 and the preorbital, which is covered above by the lateral extension of the frontal.

The other special ossifications of the sensory system—tubes on the frontals, supratemporals, supracleithra, preopercles, etc.—are described in their proper places.

UPPER JAW

There are but two elements in the upper jaw (Fig. 3): the *premaxillary* and the *maxillary.* Both are slight, slender, and possess slight function. They are toothless, the entire dorsal dentition being borne by the vomer and palatines. The premaxillary is curved around the snout and attached for its full length to the maxillary. The maxillary is broadened posteriorly where it lies for the most part under the lachrymal. Anteriorly it is slender, but more heavily ossified, and ends in a knob which rests against the cranium.

MANDIBLE

The mandible (Fig. 3) is made up of the *dentary*, *articular*, *angular*, *sesamoid articular*, and *Meckel's cartilage.* The dentary is little larger than the articular. The two bones are overlapped along their junction and firmly ankylosed together. This bond is further strengthened by the heavy Meckel's cartilage, the largest part of which is borne by the articular, but which ends anteriorly in a cavity in the dentary. The lower edge of the dentary is heavy and thickened and, except for the small angular, forms the entire ventral edge of the mandible. The dentary bears no teeth, but the dental surface is sharp and well ossified and could be useful in a shearing action. Along the outer side of the lower edge of the dentary is the tube of the sensory canal. Posteriorly its ventral edge is not completely closed, but anteriorly it is completely closed and tubular and opens to the surface by pores. The sesamoid articular is slenderly ovoid, with its long axis antero-posteriorly. It is thin and rests on top of the columnar Meckel's cartilage. On it is inserted the adductor mandibularis. The articular end of the articular, with its facet, is thick and bulky. The major part of this formation appears to be an ossification of the posterior end of Meckel's cartilage and, therefore, endosteal in origin. The triangular angular is small, but heavy. Its entire posterior end is the surface of insertion of the ligament from the interopercle.

PALATINE ARCH

The elements of the palatine arch (Fig. 3) which are present are the *palatine*, *pterygoid*, *quadrate*, *mesopterygoid*, and *metapterygoid.* The palatine is long and rather slender, but well ossified. It bears a band of tiny conical teeth on its anterior end. They are about thirty in number and arranged irregularly in three rows. The teeth are similar to those of the vomer and are continuous with those. This is made possible by the fact that the dentigerous end of the palatine fits closely in a groove between the ventral ethmoid, ethmoid cartilage, and vomer. For this reason it would be easy in undissected specimens to conclude that all the teeth are on the vomer. The dorsal side of the palatine for its entire length is securely attached to the ethmoid cartilage. At its posterior end the palatine sends a short, superficial splint of bone along the external side of the pterygoid which serves to bind the two bones more tightly together.

The broad, rather thin pterygoid is irregular in shape. Instead of a clean junction with the quadrate, separated by cartilage, the pterygoid extends a short way along the inner side of the quadrate along the entire edge of junction, and there is, furthermore, a small flange which overlaps the quadrate externally, thus locking the bones securely together. There is a thin, superficial, larger ossification extending from the pterygoid dorsally over the cartilage of the region to lie along the anterior side of the prefrontal, making the junction of the palatine arch to the cranium more secure.

Beside the normal quadrant-shaped main body of the quadrate, and the condyle of articulation for the lower jaw, both of which are heavily ossified, the bone is notable for the length and size of the posterior process which is sent back along the anterior arm of the preopercle. This spike is longer than the main body of the bone. From the lateral aspect it appears razor-thin, but seen dorsally it appears as a broad process tapering to a sharp point under the bend of the symplectic. It lies between the preopercle and the anterior process of the symplectic and binds all these elements together.

The mesopterygoid is much the largest bone in the palatine series. Although broad and long, it is quite thin and pliable. The mesial, or dorsal, end is fairly straight and is bound to the parasphenoid along its entire length. The lower edge is overlain respectively by the metapterygoid, quadrate, pterygoid, palatine, and the cartilage in this region. It forms the roof of the mouth. Although it bears no teeth, there is a rounded patch of heavier ossification in the region of the pterygoid which is perhaps intended for opposition to the large glossohyal teeth below. The bone is shallowly concave on its outer side.

The metapterygoid is a small, thin, triangular bone. The spike-like dorsal end lies against the hyomandibular and the broader ventral end rests on the mesopterygoid. Its strengthening function must be negligible.

HYOID ARCH

The cartilage-capped articular head of the *hyomandibular* (Fig. 3) and the heavily ossified supporting structure form the principal part of the bone. The opercular condyle, which is borne on a short shaft, is likewise heavily ossified. The dorsal angle between it and the articular head of the bone is filled with a wedge of lighter ossification. On the lateral face of the articular head a ridge of bone projects posteriorly and outward. The dorsal part of this ridge slightly overlaps the preopercle and serves to wedge the dorsal end of that bone securely against the opercular condyle. The ventral shaft of the hyomandibular, while not especially broad, or as heavily ossified, as the articular head, is thick and sturdy. A part of its ventral end is covered by the angular flange of the preopercle, and the bones are here again securely bound together by membranes. But between this point and the lateral, more dorsal, ridge of the hyomandibular there is a considerable open space between the two bones. In the anterior angle between the articular head and the ventral shaft is a broad wing of thinner bone.

The *symplectic* (Fig. 3), as usual, is separated from the hyomandibular by a short column of cartilage. It is a long, slender bone, only half the width of the ventral shaft of the hyomandibular. Its long anterior portion is bound to the posterior process of the quadrate and ends in a pad of cartilage in a little concavity on the posterior side of the main body of the quadrate. There is a slight wing of light bone in the broad dorsal angle of the symplectic.

The *interhyal* (Fig. 5) is small but stout. The broad base is capped with cartilage and attached to the epihyal. The more pointed dorsal end is likewise capped with cartilage and inserted in a tiny cup on the inner side of the cartilage between the hyomandibular and symplectic.

The *epihyal*, *ceratohyal*, and two *hypohyals* (Fig. 5) form a long, slender, but heavily ossified, connection between the gill arches and the hyoid arch. The epiphyal is only about one-third the length of the ceratohyal. Around its lower edge and between the two bones is a narrow band of cartilage. The last two branchiostegals are inserted on the side of this cartilage. The two hypohyals are heavy, small bones, the interior of which remains cartilaginous. The dorsal one is securely bound to the junction of the glossohyal and the first basibranchial. On the ventral one is inserted the short, tough ligament of the urohyal.

There are seven *branchiostegal rays* (Fig. 5), all thin and pliable. The first five are attached to the ceratohyal; the last two to the epihyal. The first is tiny, short, and slender. The second is a little broader, but is much longer. The third is somewhat broader and a little longer. The remaining four are broad and have the curved shape of the blade of a saber, each with the proximal end shallowly furcate, and the ventral edge of the blade flattened distally.

The *urohyal* (Fig. 6) is a long, thin, pliable bone, the main part of which is in a vertical plane and lies between the sternohyoideus muscles. The anterior end is slender, strongly ossified and nearly circular in cross section. It splits into two slender rods which reach nearly to the two ventral hypohyals to which they are inserted by very short but stout ligaments. The appearance is that the ligaments have been ossified nearly to the hypohyals.

OPERCULAR APPARATUS

All four opercular elements are present (Fig. 3). The *opercle*, *subopercle*, and *interopercle* are very thin and pliable. Only the facet of the opercle and a short supporting ray behind it are more strongly ossified. The opercle is much the largest of the bones. Its lower edge slightly overlaps the entire dorsal edge of the subopercle and the bones here are tightly bound together by connective tissue. There is only a slight crack of open space between the opercle and preopercle, and the lower part of this is filled by the dorsally projecting process of the subopercle. The interopercle is a long bone nearly entirely hidden from lateral view by the preopercle. It is firmly bound to the subopercle posteriorly, and a short ligament connects it with the angular anteriorly. The *preopercle* is little more than a tube for the sensory canal. The anterior arm is longer than the vertical arm and the two come together at only a little more than a right angle. In the angle is a broad wing of thin bone which overlaps and is bound to the hyomandibular and symplectic. The anterior arm is an open trough. At the angle is a bridge of bone across the trough. The dorsal arm of the bone is made at least semitubular by three other such bridges of thin bone.

GILL ARCHES

The *glossohyal* (Fig. 7) is peculiar because of its dentition and the fact that the dental cement bone is so much larger than the ossification of the glossohyal itself. Only the posterior end of the glossohyal cartilage is ossified where it articulates with the first basibranchial and where the dorsal hypohyals are inserted. The remainder of the glossohyal cartilage extends anteriorly as a long, sturdy rod to the anterior end of the dentigerous surface. The dorsal and lateral surfaces of the cartilage are covered by the thin, dental cement bone. This is purely superficial and can be teased off the cartilage. The two sides do not meet ventrally and the cartilage is there exposed for its full length. This ossification bears nine strong, recurved, conical teeth around its anterior edge, but none at all on its shank in the smaller specimen. The larger specimen has six teeth, as shown in Fig. 7. The teeth are longer than the bone is wide at this point.

The first *basibranchial* (Fig. 7) is very thin, but deep. It is deeply indented on its posterior edge. Here it sends a slender spur posteriorly to the second basibranchial. This bone sends a similar spur from its dorsal edge to the first basibranchial. In between these two spurs is a rectangular open space of some size. The hypobranchials of the first arch are inserted in this open space above the junction of the ventral spur of the first basibranchial with the second basibranchial. The long, slender second basibranchial becomes broader posteriorly but from lateral view it tapers posteriorly until at its junction with the third basibranchial it is more nearly circular in cross section. The third basibranchial is short and shaped like an awl, with the point posteriorly. The fourth basibranchial is broad, has a flat dorsal surface, and is entirely cartilaginous. From its posterior end a short nubbin of cartilage projects along the floor of the oesophagus between the fifth ceratobranchials.

There are *hypobranchials* (Fig. 7) on the first three arches. Those of the first are narrow, slender rods of bone hardly half the length of the ceratobranchials. Those of the second arch are similar in shape but considerably shorter. The hypobranchials of the third arch are broad and short. They are inserted by their *distal* ends to the anterior edge of the fourth basibranchial and the ceratobranchial. The proximal end is cartilage-capped and projects ventrally as in the osmerid fishes.

There are five pairs of *ceratobranchials* (Fig. 7). They are long, slender bones which become progressively broader, heavier, and shorter, from those on the first arch to the fifth. Those of the third arch are inserted not only on the hypobranchial but on the fourth basibranchial. Those of the fourth and fifth arches are inserted by broad bases on the fourth basibranchial. The ceratobranchials of the fifth arch have expanded proximal ends and on the base so formed on each is a group of several small, blunt, conical teeth.

Epibranchials are present on the first four arches. Furthermore, on the distal end of the fifth ceratobranchial a short rod of cartilage extends inward that may represent the unossified remnant of a fifth epibranchial. The first epibranchial is similar in size and shape to the ceratobranchial. But near its mesial end a short, slender, cartilage-capped projection meets a similar process from the second suprabranchial. There are similar processes for the same purpose on the second and third epibranchials and on the third and fourth suprabranchials so that the gill arches are securely bound together dorsally. The epibranchial of the fourth arch is entirely cartilaginous. It is a simple rod projecting dorsally from the ceratobranchial very much like the condition in *Bathylagus* and *Microstoma* where this cartilaginous fourth epibranchial is attached along the posterior edge of the expanded fourth suprabranchial.

The first *suprabranchial* is a slender, simple rod extending upward from the gill arches to the parasphenoid. It is attached proximally to the first epibranchial and second suprabranchial. Both ends are capped with cartilage. The second suprabranchial is flattened with a pointed, cartilage-tipped anterior end, a pointed cartilage-capped process for articulation with the first epibranchial, and a truncated posterior end which is likewise cartilage-capped and joined to the second epibranchial. The third suprabranchial is quite like the second only a little longer and with a broader posterior end to which are attached not only the third epibranchial but the cartilaginous anterior end of the fourth suprabranchial. The cartilage of the anterior end of the bone is not attached to anything. The fourth suprabranchial is greatly expanded dorsally. A well ossified rod extends from the ceratobranchial mesially, in a position normal for the epibranchial. From the anterior end of this a similar heavily ossified rod extends at a posterior angle dorsally and is of the same length as the first rod. It is capped with cartilage at the end. Between these rods of heavier ossification is a wedge of thinner ossification that makes up most of the surface of the bone. On the posterior surface of this high bone is inserted the broad muscle which extends ventrally to the ceratobranchial below.

On the cartilaginous anterior end of the fourth suprabranchial is borne an oblong, superficial dental cement bone which is covered by a group of about twelve short, conical teeth that oppose those on the fifth ceratobranchial below.

PECTORAL GIRDLE

The dorsal fork of the *posttemporal* (Fig. 8) is larger, broader, and stronger than the ventral fork. It lies just under the skin and is attached by ligament to the epiotic. The main body of the bone bears on its outer side a short, well-ossified tube that carries the lateral line canal, which is open at either end. The ventral fork is slender, nearly circular in cross section and, like the anterior forks of the urohyal, it appears that the ligament has ossified nearly to the bone of attachment, the opisthotic in this case. It is stiff and stands at nearly right angles to the main body of the bone and the dorsal fork, instead of being in the same plane, as is usual. There is a shallow, broad facet on the inner side of the bone for attachment to the supracleithrum.

The *supracleithrum* (Fig. 8) has a constricted knob at its dorsal end which is attached to the posttemporal. The dorsal third of the bone is thickened by the short tube of the lateral line canal which it bears on its outer surface. The rest of the bone is thin and flat. The bone is slightly concave dorsally to conform to the curvature of the body.

For the most part, the *cleithrum* (Fig. 8) is a thin, flat bone. There is a short dorsal spike from which a ray of heavier ossification extends downward to the insertion of the primary shoulder girdle. Here it is met by a similar strongly ossified ridge from the anterior edge of the ventral arm of the bone. This ridge projects on the inner side of the bone and to this is attached the primary shoulder girdle. A wing of bone projects inward from this ridge to lie over the edge of the coracoid, where there is a slight groove for its reception, and binds the primary shoulder girdle more firmly to the cleithrum.

The primary shoulder girdle (Fig. 8) projects downward at more than a right angle from the cleithrum. The *mesocoracoid*, although slender, and simple, is well ossified and well formed. It ends ventrally in a broadened base on the cartilage between the scapula and coracoid. The edges of those bones are raised to form a simple column for its reception. The bone tapers rapidly to the slender dorsal end where the bone becomes thin and slender and turns posteriorly along the inner surface of the cleithrum to the cartilage over the scapula, thus serving to strengthen the junction between the cleithrum and the primary shoulder girdle.

The *scapula* is large and well ossified. The oval foramen lies nearly in the center of the bone. The lateral edge is straight and attached for its whole length to the cleithrum. The posterior side bears a deeply indented and heavily ossified facet for the articulation of the first ray of the fin. The entire mesial edge participates in the formation of the raised base for the mesocoracoid. It is separate from the coracoid by a narrow band of cartilage. This band expands anteriorly into a broad, thick triangle, the edge of which joins the cleithrum.

The *coracoid* is normal in shape with a short, blunt, posterior process. The anterior process, which attaches to the anterior end of the cleithrum, is long and slender and leaves a broad interosseous space between the coracoid and cleithrum. The posterior edge is thickened and raised to participate in the mesocoracoid base. There are four proportionately large *actinosts*. The first three are inserted on the scapula; the fourth on the scapula and the adjoining cartilage, but not on the coracoid. There is a continuous band of cartilage around the distal ends of the actinosts, over which the fin rays ride, and each of these bones is also capped with cartilage. The first actinost is nearly as broad as long. The remaining bones are also broad, without the typical hour-glass shape, but they become progressively longer until the fourth is three times the length of the first. It is as long as the scapula.

There are four *postcleithra* on the pectoral girdle of the smaller specimen, here described, but only three on that of the larger specimen, illustrated in Fig. 8. The bones are superficial, covered only by thin skin and are visible externally. All are thin. The uppermost is nearly circular and small. It overlaps, and is there bound to the second and also to the cleithrum and supracleithrum. The second is nearly four times the length, and as broad, as the first. The third is only half the length of the second, and is only a little slenderer. The fourth is as long as the second and third, but is less than half as broad. It is attached ventrally to the posterior process of the coracoid and it appears that the whole series is at least a partial support for the primary shoulder girdle. The fourth postcleithrum lies wholly under the pectoral fin. These bones were apparently overlooked by Kendall and Crawford (1922). Unless stained they could easily escape observation by being torn off with the skin.

AXIAL SKELETON

There are 53 vertebra plus the single upturned caudal element, of which 36 are abdominal and seventeen caudal. There are no ribs on the first two. Their places on the centra are taken by ligaments between the cleithrum and supracleithrum and serve to bind the shoulder girdle to the axial skeleton. The ribs on the next 24 vertebrae are adnate to the centra. On the twenty-seventh centrum are short parapophyses to which the ribs are attached. These parapophyses become progressively longer on the remaining nine abdominal vertebrae, and from then on each pair unite ventrally as the haemal spines of the caudal vertebrae. There are no epipleurals on the first nineteen ribs. The next fifteen ribs bear long, slender epipleurals. On the first six of these the epipleurals seem to be ankylosed to the heads of the ribs. The ribs are, in this place, thick and heavy and perhaps represent the fusion of ribs and parapophyses. On the last nine abdominal vertebrae the epipleurals adhere to the parapophyses at the side of the junction with the rib. On the first eight ribs there are slender tendons of the same size and attached in the same position as the epipleurals. It is believed that they are homologous, and also that the ligament on the first vertebra is likewise homologous, with the epipleurals. No sign of epipleural or tendon is seen on the ribs between the ninth and twentieth vertebrae and it is not believed that they were accidentally removed in dissection.

On the first 27 vertebrae are borne long, slender epineurals, quite similar in shape and length to the epipleurals. They are attached at the base of the neural spine and seem to be ankylosed thereto.

The neural spines on the abdominal vertebrae are all slender and pliable. The two spines of each vertebra do not become united into a single spine until the twenty-first vertebra, which is the third behind the dorsal fin. The spines beyond this point become progressively heavier and stiffer.

There are eight thin, but broad, interneurals which fill nearly all the space between the neural spines and the top of the body. The first interneural is enormously expanded, and is much broader than any of the remaining ones.

There are 12 pterygiophores for the dorsal fin. The first is inserted between the neural spines of the ninth and tenth vertebrae, well in advance of the first ray of the fin, and the last, which is tiny, lies between the nineteenth and twentieth vertebrae. The second is the longest and largest, although all of the first three pterygiophores are broad and long.

The rays of the anal fin are borne on thirteen slender pterygiophores between the haemal spines of the first eight caudal vertebrae.

The support of the caudal fin is typically homocercal with a single upturned centrum. The neural spines and haemal spines of the next five anterior vertebrae also lend at least some support to the ray of the fin, the neural spine of the penultimate vertebrae being especially shortened and broadened for this purpose.

RELATIONSHIPS

A review of the anatomy of *Argentina* makes understandable the long association that the argentines have had with the salmonoid fishes in ichthyological systematics. The general shape and proportions of the head and body, the disposition of the fins on the body, the presence of an adipose fin, orbitosphenoid, basisphenoid, the broad and deep myodome, which opens posteriorly, the well-formed and functional mesocoracoid, the several postcleithra, and the peculiarly inverted third hypobranchials (which are so reminiscent of the osmerid fishes) are all typical of the salmonoid fishes. But, on the other hand, the argentines in common with the other opisthoproctoid fishes, and in distinction from the salmonoid fishes, have the following characteristics: (1) Dentition is completely lacking on the premaxillaries and maxillaries, and these bones are much reduced in size and function; (2) there is complete lack of supramaxillaries; (3) the anterior portion of the palatine arch is strongly bound by both cartilage and bony articulation with the ethmoid region of the cranium in the characteristic opisthoproctoid manner; (4) the broad and long mesoptergoid which is obviously destined to aid in the support of the enlarged eye has its ventral edge *under* the cartilage of the palatine arch, not in the same plane with it, and for its entire mesial length it is bound tightly to the parasphenoid; (5) the mesopterygoid and metapterygoid are obviously membrane, not cartilage, bones and the latter is much reduced in size and function; (6) the hyomandibular articulates broadly across the entire lateral edge of the posterior part of the cranium, from the posterior edge of the pterotic to the anterior edge of the sphenotic; (7) the vomer is characteristically broad and thin, has a long posterior shaft (in distinction to the osmerids), and a single row of teeth around the anterior edge which, with the palatine teeth, form the entire dorsal dentition of the mouth; (8) the supraoccipital is broadly shut out from the foramen magnum by the exoccipitals; (9) the fish are exclusively marine and typically bathypelagic with pelagic eggs and larvae (Schmidt, 1918) in abrupt distinction to the normal demersal eggs of salmonoid fishes which are typically buried in, or adhere to, gravel, either near the intertidal area or in fresh water; (10) the cartilage of the cranium, especially of the ethmoid region, is much less developed than in the salmonoids; and last, but by no means least, (11) there is a well-formed and apparently functional spiral valve in the intestine as in the other opisthoproctoid fishes, quite in distinction to the vestigial remnants of spiral valves encountered in occasional specimens of salmonoid fishes (Kendall and Crawford, 1922).

For these reasons the Argentinidae are to be considered as members of the suborder Opisthoproctoidei of the order Isospondyli, although without question they go a long step toward bridging the gap between those bizarre inhabitants of the ocean depths and normal isospondylous fishes. In a group of fishes the members of which are typically widely different from the other members, the Argentinidae diverge especially far, anatomically speaking. To the rest of the Opisthoproctoidei they stand in much the same relation as the Esocidae do to the other families of haplomid fishes: widely divergent, but descended from a similar stock.

The following synopsis of the Argentinidae will serve to distinguish this family sharply from the other opisthoproctoid fishes (Opisthoproctidae, Macropinnidae, Winteriidae, Xenophthalmichthyidae, Bathylagidae, and Microstomidae). Of these fishes it is most closely related to the Microstomidae.

Synopsis of the family Argentinidae.—Opisthoproctoid fishes with several postcleithra, mesocoracoid, basisphenoid, opisthotics, large air bladder, premaxillaries, laterally directed eyes, and a broad myodome that opens posteriorly.

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CHEMISTRY.—*A study of ionic adsorption in solutions of silica and alumina.*[1]

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Some years ago I noted an acid solution of clay that became more acid on the first addition of ammonia. Recently a similar but more pronounced effect was found on adding an alkali to dilute water solutions of pure silica and alumina. This led to finding alkaline solutions that became more alkaline on adding acid. Aside from their purely chemical interest, these findings suggest possible explanations of some puzzling mineral replacements, and the field seemed worth thorough exploration to determine its limits and underlying principles. This task is far from completed but a first summary of results seems in order.

Electrometric titration was the method chiefly used. This gave a series of pH values varying with the amount of reagent added to the solution being studied, which plot in a smooth curve readily repeatable. From among dozens of curves run, I have selected four groups of three concentrations each. These are (1) silica solutions and (2) alumina solutions, each titrated with potassium hydroxide and (3) potassium silicate and (4) potassium aluminate, each titrated with hydrochloric acid.

Impurities were carefully avoided, but it was later found that they had little effect on the shape of a curve, only displacing it slightly. Filter paper, because of its strong adsorption of cations, was not used. Solutions were made up in fresh pyrex glass. Concentrations were determined in platinum. Carbon dioxide from the air interfered with two concentrations of potassium aluminate as noted below. In a freshly diluted or titrated solution a period of 10 to 40 minutes is required to attain an equilibrium pH reading.

Silica solutions are easily obtained by dissolving pure silica in distilled water— about 5 grams in a 4-liter flask. The pure silica is obtained either from silica gel or from a pure bentonite by digesting in hot strong acid for 24 hours to remove bases followed by thorough washing. In hot water, silica approaches saturation (about 0.4 gram per liter) in about 30 hours. The preparation of pure alumina stock solutions by dissolving in hot water was found not to be feasible. Alumina is soluble to the extent of only

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